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Matrix of Thermal Characters for the Blind with Temperature Control System

Abstract

In the paper the authors present the prototype of the Thermal Characters Matrix for the blind people. The prosthesis was built up with the use of many miniature Peltier modules deposited on the common substrate. The surface of every Peltier micropump is a touch point which demands the thermal stabilization [1]. Miniature Peltier modules behave both as heat and cold generators. They are also able to measure the required dot temperature. The control system keeps the constant temperature, no matter how the ambient conditions look like.

Introduction

The lack of common writing for the blind was the main obstacle in information interchange and acquiring knowledge. The first school for the blind was founded in Paris in 1784. Teachers tried to imprint convex letters, but students were able to read only single characters [2]. Louis Braille (1809-1852) disseminated a completely new system of writing consisting of convex dots, definitely easier to read, and gave the possibility of writing by using perforate negative character with a help of a special table [2].
Six points give a possibility to write 64 different characters. That is enough for all European alphabets and also for some additional signs (for example: +, -, ; ... etc.). Development of computer science contributed to the progress in designing new devices for the blind. Voice synthesizer enables reading text from a computer, notepad or telephone [3]. Access to Internet opens the way for unlimited knowledge sources. Blind people can easily put data into the computer with keyboard only if they have the opportunity to check the lines they have written. One way of generating Braille signs is using special mechanic or piezoelectric ruler, which has six or eight points per sign [4]. Mechanic ruler generally works like dot-matrix printer. This ruler is fast and quite cheap, but due to mechanic elements – unreliable, noisy and unpopular. Definitely better in practice is piezoelectric ruler. +/-400V is connected to both sides of piezoelectric crystal, what makes the crystal bend to one side or another. The main advantages of these devices are: reliability, very high speed, and small power dissipation. On the other hand, main disadvantages are very high price and limitation to two lines of text because of the necessary crystal length. The result of this limitation is impossibility in displaying graphics. The graphics could be shown by using electric touch panel, where dots are stimulated by electrical low frequency impulses [5] [6].
Prof. Gilbert De Mey from Belgium initiated research over thermal prosthesis for the blind people. The idea was based on controlling power dissipation in the matrix of resistor to obtain gradients of temperatures [7]. In the second prototype of the thermal matrix a research worker used LED diode instead of resistors. The diode emits thermal energy in a set direction. The fingers of the blind are able to recognise that energy. Both ways of thermal matrix have the same disadvantage – long time of waiting for the dots to cool after finishing the emission of the sign.

HOT/COLD touch dots

During International Conference of IMAPS Poland Wroclaw in September 2004 the idea of thermal matrix for the blind based on Peltier modules has been exposed [8]. A patent with the

use of Thermo Electric Coolers (TEC) gives possibility not only to generate thermal power, but also to transfer heat from one side to another. By mounting TEC on common thermal conductivity substrate it is easy to control heat transfer. A man feels cold and warmth as the difference in the temperature of the thing touched and of the human body (finger).
Now it is possible to heat or cool Braille signs, so device can reach the required temperature faster (comparing to solution supported by resistors or LED's). Moreover, to reach necessary temperature the device needs little electrical energy. A part of energy will be taken from radiator, which works as a heat capacitor. On displaying the next Braille sign, temperature should change as fast as possible. Decreasing the temperature of a dot can be done not only by stopping the heating but also by Peltier micromodule invert polarity. Energy will flow to the radiator cooled earlier. During switching the temperature under the TEC is different than over it, so heat pumping is easier. In the thermal prosthesis some dots are turned on, hot, and then they are cooling the substrate. In the same time dots turned off, cold, are heating the substrate. During cooling the touched surface, the substrate-radiator is heating, accumulating energy, which is used for heating other dots.

Earlier experiment

To build the first prototype the miniature Peltier pumps were used, each with active surface of 2mm x 2mm and containing eight pairs of Bi_2Te_3. Each Braille sign was made of eight dots [1]. All Peltier micromodules were located on the common substrate. By assuring good thermal contact, it is considered, that temperature of surface pressed to radiator is the same for all dots. The touch points were able to be cool or hot only. There was no possibility to turn off the working point. It was very inconvenient, when after long heating time, the temperature of touching surface increased too much.
While testing the first prototype by touching it we noticed that the temperature of Peltier micromodule surface changes quickly, because the temperature of human finger was different then the temperature of either hot or cold surface of Peltier micropump. Touching the heated micropump with the finger makes Peltier micromodule work in other conditions (Fig.1.).

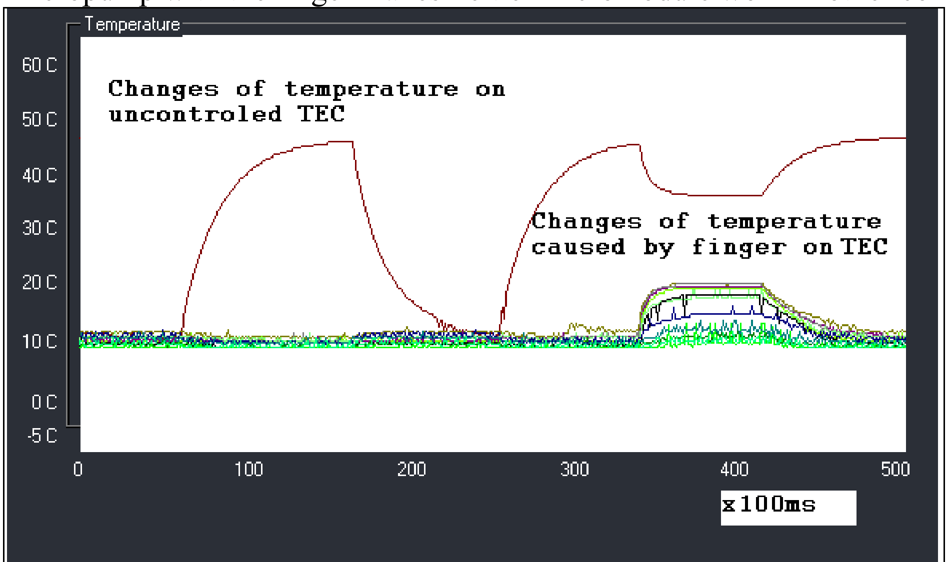

Fig. 1. Changes of temperature on TEC without stabilization.

To eliminate the mistakes above we ought to constantly control the temperature of touch surface and steer the heat micropump to set the required temperature.

The second prototype

Based on above experiences, the second prototype was built, in which the active elements were used as sensors [9].

When heat micropump is not connected to a power source it behaves as thermocouples connected in series by current and connected in parallel by thermal conduction. Then Seaback voltage U_α appears on its connections, proportional to a temperature difference ΔT between surfaces of the heat pump and proportional to the Seaback coefficient α.

The dependence between the temperature ΔT and the voltage U_α is [10]:

$$U_\alpha = \alpha \cdot \Delta T \tag{1}$$

In order to measure the temperature of the touch surface, the Peltier micromodule should be unconnected. When the TEC is not powered, the control system measures Seaback voltage, compares it to the required temperature and decides: shall the touch point be turned on or not. The control system performs measurement again after definite time.

In order to accelerate the work of the thermal signs, the current supplied to the heat micropump ought to be high, and when the difference of temperature achieves required value – the supply shall be disconnected. This manner of steering enables keeping steady temperature also when surface of Peltier micropump is touched. Peltier micromodule has to heat the material of considerably higher thermal conductance and heat capacity instead of air. Figure 2 presents acceleration of work of thermal signs with temperature control system.

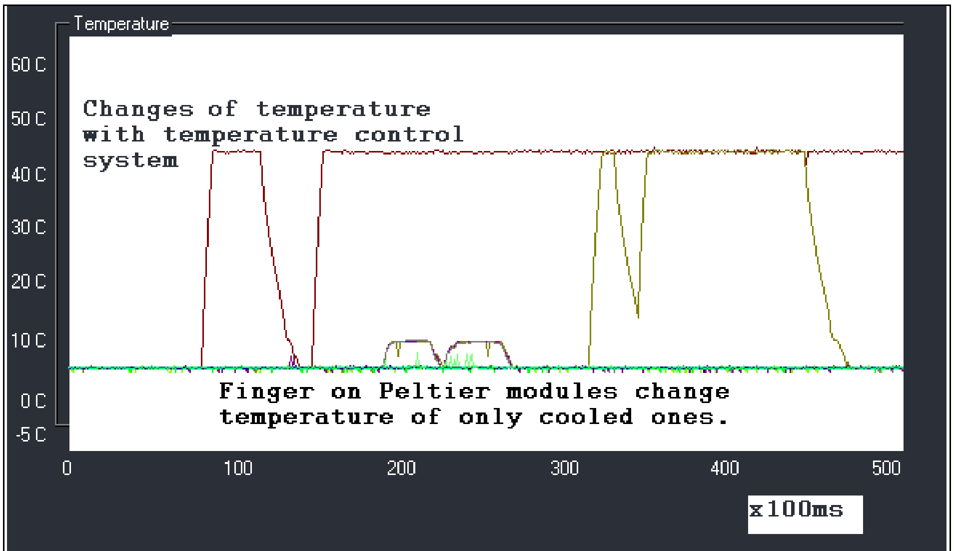

Fig. 2. Measured changes of temperature on TEC with control system.

The time constant of Thermo Electric Coolers used in the prototype is about 2,2 seconds [11]. Nevertheless, period of time that the Peltier pomp needs to achieve the target temperature was shortened to 0.2 seconds by a special temperature control system. Applying finger to the thermal signs changes only the temperature of the cooled ones. Temperature of the heated ones stays steady.

Scheme of device

The popular ATMega32 microcontroler was used to build the temperature control system. It makes a measurement of each point in a few milliseconds. The time needed for temperature measurement and decision-making equals 32 microseconds, so thermometry does not affect the quality of working of the heat micropump. Presented manner of measurement involves this method of steering the Peltier module: they are switched on or unconnected. This steering looks like Pulse Width Modulation (PWM).

When Peltier micromodule is used for cooling, then the higher than optimal current steering is purposeless, because the cold surface will supply the heat instead of taking it. But when the Peltier micropump is the heater element, then it is possible to increase the current of steering, tracking simultaneously the temperature, as not to damage the device.

To control this innovative device, special computer program was made, which enables to monitor the plot of surface temperature of each Peltier micromodule.
Window of program is showed on Figure 3:

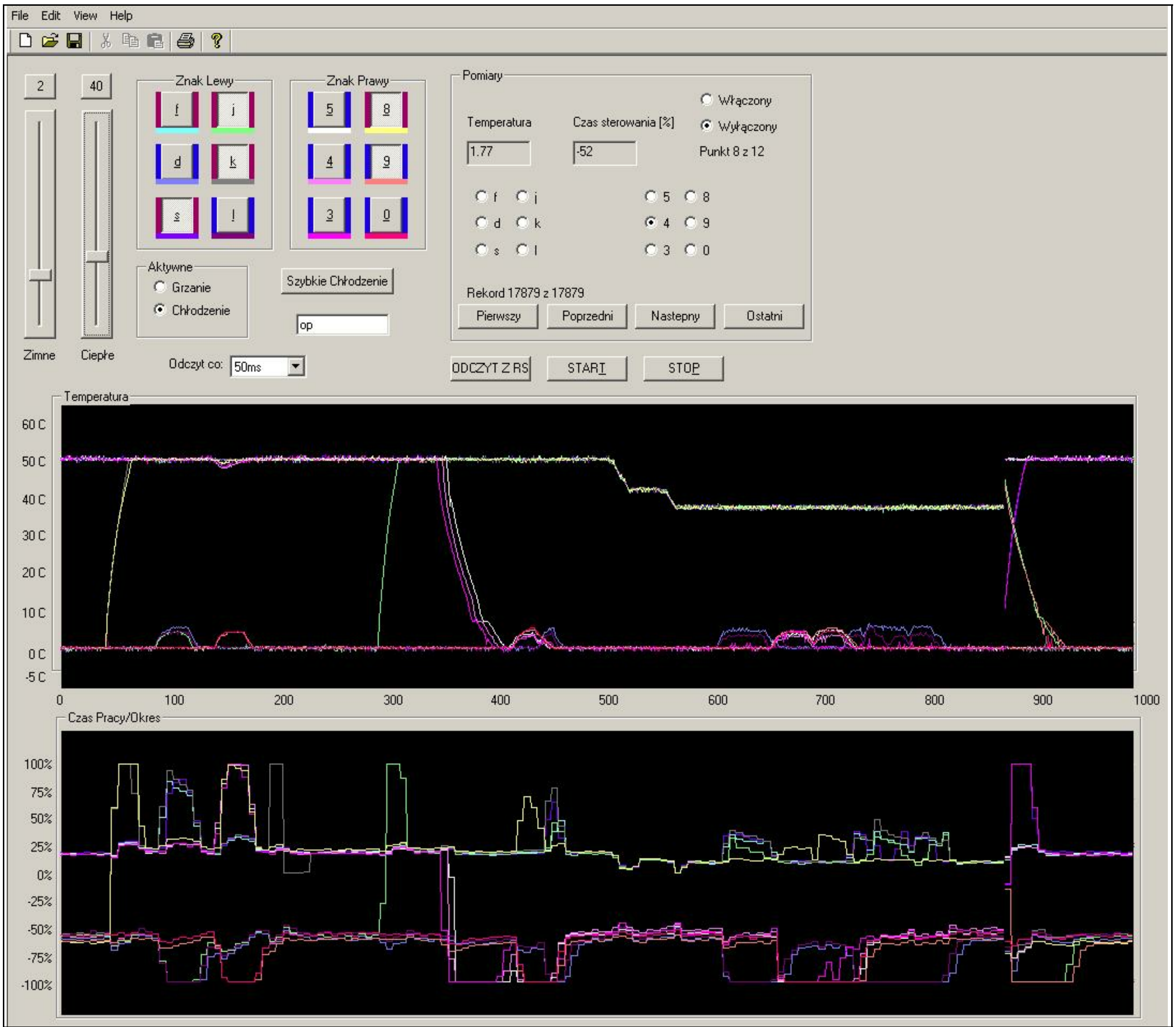

Fig. 3. Program window with plots.

Program enables to setup the touch point on required temperature with assistance of a keyboard or a mouse. All program functions have their own keyboard shortcuts. Keys F,D,S,J,K,L on keyboard switch the temperature of the dots of the Braille sign that we have on the left, keys 3,4,5,8,9,0 switch the dots of the right sign. Darts up/down and keys Page Up/Page Down set the required degrees of the hot and cold temperature of the touch surface.
Each temperature of touch points is pictured on overhead diagram showing the work of the prototype.
The bottom diagram pictures, in percentage, how many times a Peltier micromodule was turned on in the period of 100 last measurements. Positive values mean that the touch surface is heating, negative – that it is cooling. Thanks to this plot, it is easy to deduce which of the Peltier modules is being touched at this time, because the touch of the human finger increases

the demand for thermal energy needed to keep the fixed temperature.
Temperature values and percentage of working time can be read off from the Fig 4.:

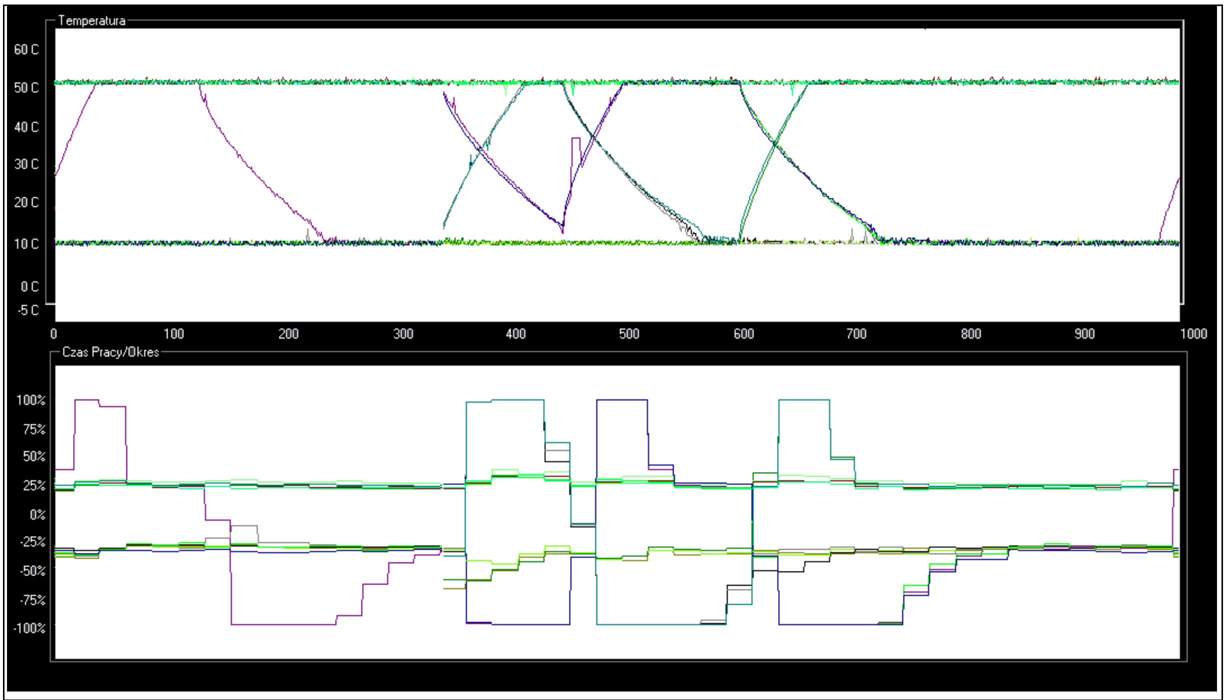

Fig. 4. Plots of temperature and percentage of work time.

The photos of the fully set device are shown on figure 5 and 6.

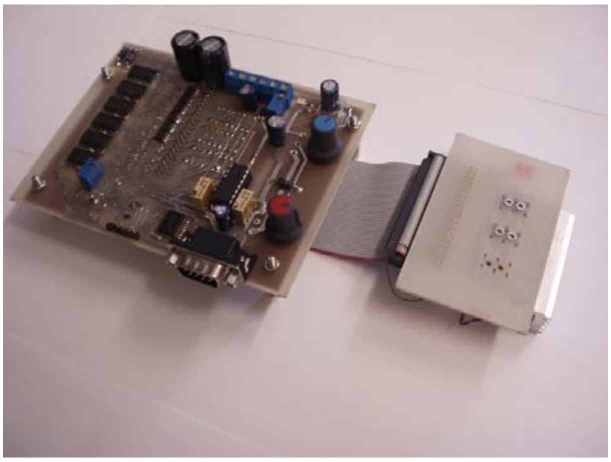

Figure 5. Second prototype of the thermal matrix

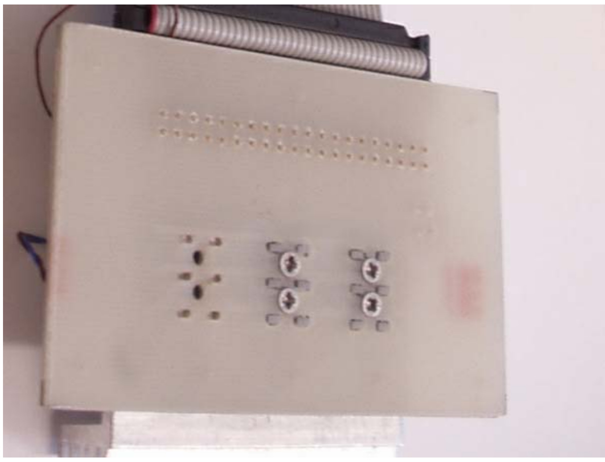

Figure 6. Touch panel with small Peltier pumps

By using the thermographic MK525 camera, a few photos have been made. Dark places mean temperatures over 10^{o}C, bright – below 40^{o}C.

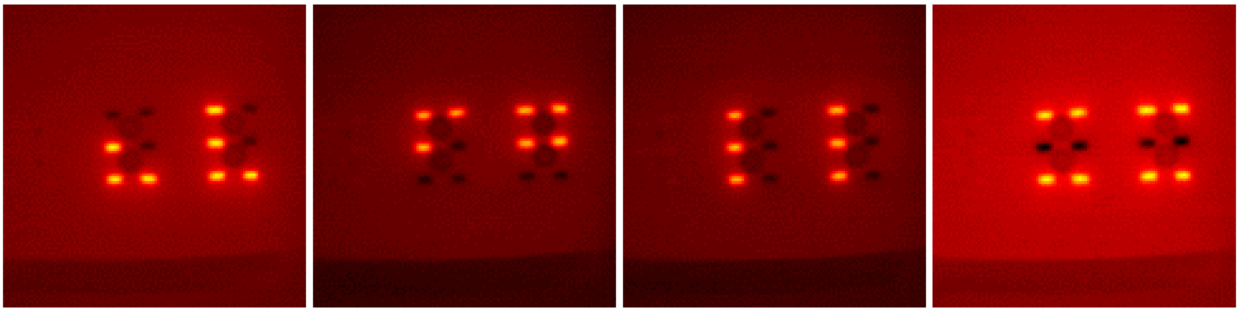

Figure 7. Thermograph photos of the thermal matrix for the blind

The Figure 7. presents gradients of temperature of each Peltier micromodule. The hot dots in each Braille sign have the same temperature.

Clinic tests

During realization of this device, same question appeared: Will blind people be able to recognise this kind of Braille characters? Is it better to cool or heat the active dots? Which range of temperature is optimal?
The blind people have made the first test of this device.

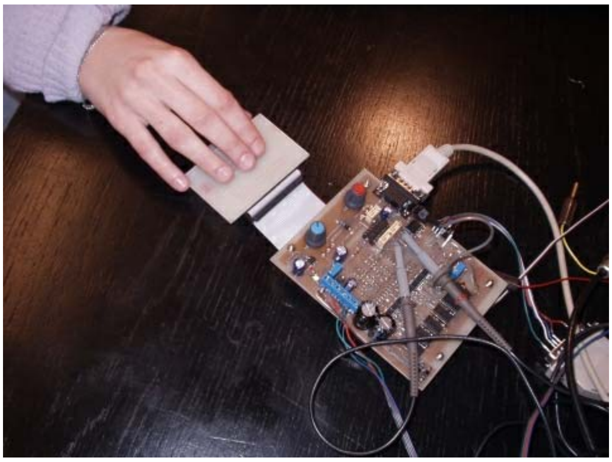

Figure 7. Blind person testing thermal matrix

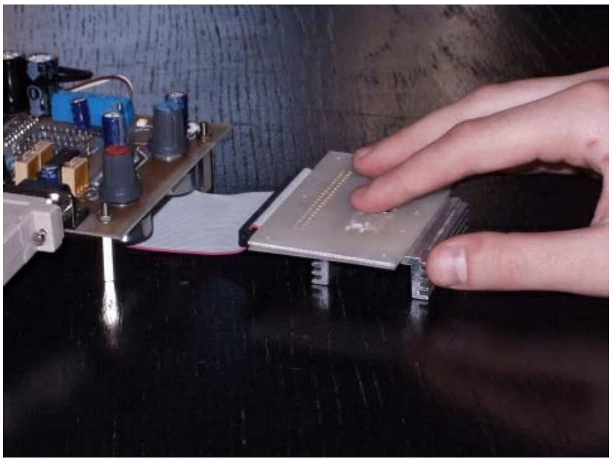

Figure 8. Training in reading thermal characters

A man and a woman from the Centre for the Blind and Half-Blind Children in Krakow have met for the first time with this kind of device.
Experiences with the use of the first prototype, without temperature stabilization, showed, that invited people distinguished the sign when all dots were hot or cold, but the trials of reading any single letter failed in nine per ten tests and took a lot of time. After two hours of testing, the blind woman was able to recognize 50% of the characters displayed. Even for people with very sensitive fingers this kind of experience requires long hours of exercises. According to the blind people, hot dots were subjectively easier to recognise than the cold ones. Maximum temperature shouldn't exceed 50^{o}C, and minimum must be over water's condensation temperature.
During testing the second prototype, with temperature stabilization, the blind woman recognized almost all Braille signs and it took her a few seconds, Exercises carried out with the blind show, that people are able to recognize the hot and the cold dots easier. After the first hour of training in reading the blind woman was able to recognize more than 90% of displayed characters. The power consumption is so small that it makes it possible for the

matrix to be a mobile one. The regulation of touch point temperature makes the recognizing easier and more comfortable.

Conclusions

Presented experiments have shown that the use of the Peltier micropump with thermal stabilization enables the building of a faster and more efficient thermal matrix for the blind people. The touch surface of every Peltier micropump demands the thermal stabilization. The use of the TEC for the thermometry makes it possible to use the active element as the sensor.

References

[1] Krzysztof Boroń, Piotr Bratek, Andrzej Kos "Matrix of Thermal Characters for the blind based on Peltier modules". XXIX International Conference of IMAPS Poland Chapter Koszalin Darłówko, 19-21 September 2005
[2] Braille Louis, Procèdè pour ècrire les paroles, la musique et le plain-chant au moyen de points, à l'usage des aveugles et disposè pour eux. 2e èd. complètement refondue. Paris 1837 [indirectly quoted].
[3] Jakubowski S.: "Poradnik dydaktyczny dla nauczycieli realizujących podstawę programową w zakresie szkoły podstawowej i gimnazjum z uczniami niewidomymi i słabo widzącymi", Ministerstwo Edukacji Narodowej, Warszawa 2001
[4] Edwards A.D.N.: "Graphical user interfaces and blind people", Proc. of th 3 Int. Conference on Computer for handicapped persons, Wolfgang Zagler, Ed. Vienna, Austria, July 1992, Osterreichischen Computer Gesellschaft, pp. 114-119
[5] http://kaz.med.wisc.edu/24x24.html
[6] Kaczmarek K., Webster J.G., Bach-Y-Rita P., Tompkins W.J.: "Electrotactile and vibrotactile displays for sensory substitution systems", IEEE Trans. on Biomedical Engineering, vol. BME38, pp. 1-16, January 1991
[7] De Baetselier E., De Mey G., Kos A.: "Thermal image generator as a vision prosthesis for the blind", MST News, Poland, 3/1997, pp. 3-5
[8] Bratek P., Brzozowski I., Gołda A., Boroń K., Kos A., Matrix of thermal characters for the blind, Proc. of the XXVIII International Conference of IMAPS Poland Chapter, Wrocław, 26-29 September 2004, pp. 179-182
[9] Boroń K., Bratek P., Kos A., Measuring gradient of temperature based on Peltier module, Proc. of the XXIX International Conference of IMAPS Poland Chapter, Koszalin-Darlowko, 19-21 September 2005, pp. 139-142
[10] Thermoelectric Cooling, *RMT Ltd*. 2003.
[11] Thermoelectric Cooling Module type 1MT03-008-13 Specifications. *RMT Ltd.* 2005.

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